

Using the concept of uNDF in forages and seeing the results of how we have progressed with our understanding of fiber as related to ruminant nutrition it has become the next step now to better understand and quantify uNDF in plant by-products. Not that many years ago we were still using Crude Fiber, then to ADF and NDF. From there we started to understand aNDFom and now looking at uNDF we have made great strides in our understanding of rumen fiber fermentation and the impacts these feeds have on rumination, passage rate, and milk production with feed efficiency. It is the next step to look at the plant by-product feeds and what those feeds contribute with their NDF pools thus looking at uNDF in plant by-products.

It is our pleasure to post in this issue of NDS Dynamics newsletter a paper on this matter provided by the Cornell University Modeling Group.

CHARACTERIZING AND MODELING FIBER DIGESTION IN PLANT BY-PRODUCT

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INTRODUCTION

Previous work conducted in our lab demonstrated that the extent of aNDFom digestion in forages is achieved by 240 h and results in undigested aNDFom (uNDF). Further, Raffrenato and Van Amburgh (2010) demonstrated that the digestible aNDFom (dNDF = aNDFom – uNDF) of forages is fractionated into two digestible pools (fast and slow), and that forage aNDFom digestion kinetic can be characterized with a composite dynamic deterministic model (Equation 1) utilizing 4 data points as model inputs (0, 30, 120 and 240 h):

$$\text{Equation 1: } aNDFom_{(t)} = dNDF_1^{-kd_1(t-L)} + dNDF_2^{-kd_2(t-L)} + uNDF$$

The objectives of this study were: 1) understand when fermentation exhausts in plant by-products, to analyze the uNDF fraction. 2) Compare the uNDF analyzed through long term in-vitro fermentation with the indigestible fiber fraction calculated using the formula presented by Chandler et al. (1980) (2.4 x ADL) and employed in the CNCPS; and the formula proposed by Conrad et al. (1984) (ADL2/3/NDF2/3), used in the TDN equation (NRC). 3) Study plant by-products aNDFom digestion decays to understand which equation to use (simple or composite decay) for the fitting analysis. 4) Obtain the combination of 4 time-points that allow for the highest goodness of fit of the model when predicting aNDFom digestion decays and calculating aNDFom digestion rates.

MATERIALS AND METHODS

Samples of 15 plant by-products (beet pulp, canola meal, citrus pulp, corn gluten feed, corn distillers, corn germ, flaked corn, rice hulls, soybean meal, soy hulls, Soyplus, sunflower hulls, wheat distillers, wheat middlings, whole cottonseed) were collected, each from two suppliers, and analyzed in duplicate in three separate batches for aNDFom digestion using the in-vitro technique. To observe changes in uNDF the residues were analyzed at 96, 120, and 240h. Data were analyzed using a mixed effect model in JMP, and treatment effects were analyzed using Tukey's test. Significance was declared at P-values <0.05. To understand which equation to use, aNDFom digestion decays were created by analyzing feed samples up to 3, 6, 9, 12, 15, 18, 21, 24, 30, 48, 72, 120h of in-vitro fermentation. Decays were plotted on a semi-log scale to study the inflection points on the curves that reveal the aNDFom fractions. To find the time-points combination, the model selected was fit to the decays using different combination of 4 time points as model inputs, and the goodness of fit was assessed by looking at overall slope, intercept and RMSE of observed versus predicted values.

RESULTS

Fermentation exhaustion and uNDF validation: For plant by-products aNDFom digestion exhausted in most of the cases already after 120h of in-vitro fermentation, and thus the uNDF obtained. Only for Citrus Pulp residues continued to digest out to 240 h compared to 120 h residues (P-value = 0.002). Residues of uNDF recovered at 120 h were in many cases different from the ones calculated with the two equations (Table 1). Interesting is rice hulls, where its silica content acts as anti-microbial factor, thus, limiting fiber digestion Van Soest (2006). Rice hulls uNDF residue after 120 h of in-vitro fermentation was 93 percent of aNDFom, whereas using the two equations, which only consider lignin content, the uNDF calculated was much lower. Further, the indigestible fraction of aNDFom cannot be quantified by calculation, firstly because fiber indigestibility depends more on the magnitude of lignin cross linking than on lignin itself, which in turn is mainly associated to the agronomic factors and external stressors (herbivores, diseases, etc.) the plant is grown in, i.e. it is not constant. Secondly, because the equations developed to predict the indigestible aNDFom fraction are empirical and therefore they may work for the dataset from where they have been developed, but may not work for dataset built in different conditions.

Modeling aNDFom digestion behavior in plant by-products: Overall, the natural log transformation of the digestion decays reported that aNDFom is composed of one digestible fraction and the uNDF, indeed, there was one inflection point along the digestion decays of the samples analyzed (**Errore. L'origine riferimento non è stata trovata.** using Soy hulls as example). Therefore, aNDFom digestion in plant by-products can be described by the simple exponential decay (Equation 2).

$$\text{Equation 2: } aNDFom_t = dNDF^{-kd*(t-L)} + uNDF$$

Obtaining the time points: The time-points combinations selected were the beginning and exhaustion of fermentation, one time-point before and one after the decay's inflection point. Furthermore, only combinations of easy lab applicability were considered. Residues of aNDFom at 0, 12, 72, and 120h were the combination of time points that provided the best goodness of fit of model's predictions with overall slope, intercept, and RMSE being 1.00, 0.003, and 0.04 respectively (Figure 2).

Rates of digestion: Table 2 reports the rates of digestion of the plant by-products analyzed in this study with the use of Equation 2. Finally, is recommended to not use the reported rates of aNDFom digestion as reference for formulating diets, but they need to be independently calculated for each sample before being used as inputs for the CNCPS. This study provides a protocol to use for analysis of aNDFom digestion for plant by-products that associated to Equation 2 can lead to an accurate calculation of the rates of aNDFom digestion.

CONCLUSIONS

Plant by-products present a fraction of aNDFom that remains undigested over time (uNDF). 120 h of in-vitro fermentation is the time-point suggested for the analysis of uNDF in plant by-products. Long-term in-vitro fermentation associated to filtration of the residues with glass microfiber filters is an accurate method for estimating the indigestible fiber component. The calculus of the indigestible fiber fraction with the use of equations is not a reliable method. Furthermore, the digestible portion of aNDFom in plant by-products is composed of a single digestible pool that decays following a first-order behavior; Equation 2 is therefore proposed to use for modeling purposes. Finally, the time-points where to analyze the residues of aNDFom digestion, for an accurate calculation of the digestion decays are 0, 12, 72, and 120h.

Table 1. Comparison of 3 methods of estimation of not digestible aNDFom based on uNDF obtained with 120 hr of in-vitro fermentation, the Chandler's and the Conrad's equation, respectively.

Feed	Method		
	uNDF (%aNDFom)	2.4xADL/NDF	(ADL/NDF) ^{2/3}
Beet Pulp	19	28	24
Canola Meal	41	73	45
Citrus Pulp	20	19	53
Corn gluten feed	14	15	4
Corn distillers	16	26	23
Corn germ	29	23	21
Flaked corn	14	26	23
Rice hulls	93	20	21
Soybean meal	9	23	21
Soy hulls	9	10	7
Soyplus	6	9	35
Sunflower hulls	77	59	47
Wheat distillers	26	29	22
Wheat middlings	31	17	23
Whole cottonseed	57	45	49

Table 2. Digestibility and rate of aNDFom digestion of 14 by-product feeds and one commercial feed.

Feed	dNDF (%)	kd (%/hr)
Beet Pulp	81	7.0
Canola Meal	59	5.8
Citrus Pulp	80	8.1
Corn gluten feed	86	4.0
Corn distillers	84	5.2
Corn germ	71	7.5
Flaked corn	86	5.1
Rice hulls	7	40
Soybean meal	91	9.4
Soy hulls	91	4.0
Soyplus	94	2.7
Sunflower hulls	23	8.7
Wheat distillers	74	5.5
Wheat middlings	69	9.8
Whole cottonseed	43	4.0

Upcoming NDS Event

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Hotel by Denver International Airport



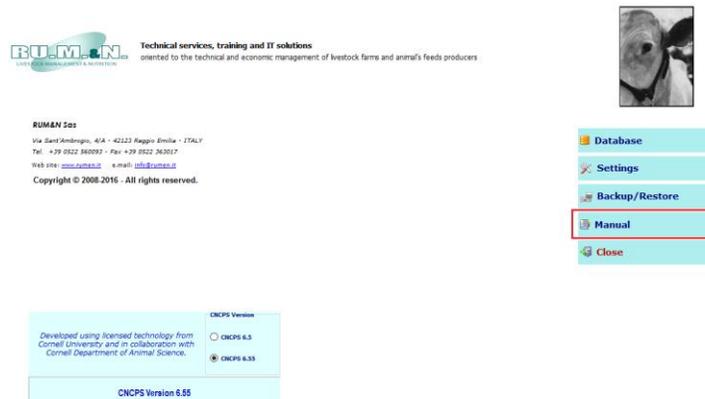
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More details to follow at a later time...

NDS Online Manual and YouTube Tutorials

Please make use of the HELPS that are available using NDS. The On-Line Manual has many PDF to show features of the program and help explain the uses. Also the You Tube channel which also can be accessed from the On-Line Manual front page has many of the training videos. Look forward for these to be updated in the next month!

Online Manual can be accessed via the NDS Professional Software front page



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